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AUTHOR	Lauer, Tobias; Ottmann, Thomas
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ABSTRACT

Experience has shown that the production of rich-media content for Web-based courses tends to be extremely cost- and time-consuming. One way for campus-based universities to reduce authoring costs is to automate the production process by using suitable tools for capturing live lectures. This paper describes different technical approaches to presentation recording. Recording systems can be evaluated with respect to a number of criteria, such as recordable input formats, automatic structuring of captured contents, synchronous replay of graphical annotations, and many more. This paper presents a list of these criteria and gives an overview of several existing software tools. It also addresses features, which are not supported by the currently available systems, but which are important for a widespread acceptance of presentation recording, such as more comfortable system-user interaction or a both powerful and efficient representation of electronically captured handwriting. (Contains 16 references.) (Author)

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Means and Methods in Automatic Courseware Production: Experience and Technical Challenges

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Tobias Lauer, Thomas Ottmann
Institute of Computer Science
University of Freiburg
Germany
E-mail: {lauer, ottmann}@informatik.uni-freiburg.de

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Abstract: Experience has shown that the production of rich-media content for web-based courses tends to be extremely cost and time consuming. One way for campus-based universities to reduce authoring costs is to automate the production process by using suitable tools for capturing live lectures. In this paper, we describe different technical approaches to presentation recording. Recording systems can be evaluated with respect to a number of criteria, such as recordable input formats, automatic structuring of captured contents, synchronous replay of graphical annotations, and many more. We present a list of these criteria and give an overview of several existing software tools. We also address features which are not supported by the currently available systems but which we consider important for a widespread acceptance of presentation recording, such as more comfortable system-user interaction or a both powerful and efficient representation of electronically captured handwriting.

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1. Introduction: Online vs. Offline Teaching

Campus-based universities are used to offering their courses in the traditional, time and space bound mode to their students. At least in systematically structured subjects like science and engineering, including computer science, the whole organization of the curriculum follows the traditional workflow: Lecturers present contents in ex-cathedra lectures; we call this the presentation phase. These lectures are usually accompanied by tutorial sessions where weekly or biweekly assignments submitted by the students are discussed. Finally, in a third, also clearly identifiable phase of the learning cycle, students apply their acquired knowledge in project and thesis work. This way, universities are able to adapt their knowledge mediation to recent research developments in a quick and flexible way.

On the other hand, the ubiquitous availability of the Worldwide Web has had the effect that even campus-based universities are increasingly trying to loosen the time and space constraints of their studies by offering web-based courses. However, they experience that running courses in a distance mode requires a complete structural change of the traditional workflow. The different phases of the learning cycle are interweaved in a fine-granular manner; not only tutorial guidance over the net but all administrative and management tasks have to be handled in a new way for off-campus students. The most unpleasant experience, however, is that courseware production and implementation can be extremely expensive and time consuming. Experience gained in several large-scale projects in Europe has shown that production costs for rich-media content in the range between 50,000 and 100,000 EUR per weekly lecture hour are no exceptions. A successful strategy to virtualize parts of the curriculum at campus-based universities should therefore not only follow the traditional workflow more closely but must also drastically reduce the production costs of web-based courses.

One first step in this endeavor is to capture the media streams occurring in live presentations and integrate them to form synchronized multimedia documents for offline use. In the following, we describe different technical approaches to this process known as presentation recording. We provide a list of criteria according to which presentation recording tools may be compared and give an overview of several existing systems. We will draw on our own experience from the past years of capturing real-life university courses using our own recording technology. Finally, we shall address some challenging aspects that are unsolved

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in most of today's presentation recording systems. The technical problems to be solved in this context also concern the user interface for lecturers and methods to represent and compress electronically captured handwriting efficiently.

2. New Option: Presentation Recording

Presentation recording is by no means restricted to one particular technical approach. There is, in fact, a variety of technologies used in the systems that can be found in research projects and on the market today. When talking about presentation recording, the first thing coming to a lot of people's minds is taping a course with a video camera. That way, even traditional blackboard-and-chalk lectures can be made available by turning the recording into a streaming-media document and storing it on a streaming server. This way of recording is pleasing for the lecturers. They can keep to their usual way of teaching, do not have to adapt to new technology and are thus able to fully concentrate on the contents. We have experimented with this method and made the experience that acceptable quality can be achieved only if a large amount of personal and technical effort is invested both during and after the lecture: Skilled technical staff must be present for taking the video and audio recordings, the video must be enhanced by high resolution digital images of the blackboard in order to increase readability, and the recording has to be structured into meaningful sections manually. We do not see how all the necessary steps may ever be fully automated such that videotaping will become a feasible method for virtualizing live lectures. Similar arguments also apply to videotaping lecturers using overhead slides.

Using a computer-based presentation system fortunately offers more attractive alternatives for presentation recording: Instead of a video camera, the computer can take care of capturing the lecture, and in much better quality. Of course, some additional hardware is required, such as a (wireless) microphone and a suitable input device like touch-sensitive whiteboards or pen-sensitive LCD tablets. Occasionally, a small amount of extra preparation may also be necessary, like converting slides to a different format, but in general, the workload remains the same as it is without recording, and no support personnel is required during the lecture.

Regarding the recording software, there are at least three different alternatives. One is to make use of existing presentation systems and add a recording functionality. Examples include PowerPoint's built-in narration option, or MS-Producer for PowerPoint (Microsoft 2002). The resulting documents may preserve all the features of the original presentation or just consist of static pictures, depending on how the slides are processed during recording.

Another approach is screen grabbing. The capture software records any screen or window content together with the instructor's audio, producing a synchronized video output. An examples hereof is Camtasia (TechSmith 2002). The definition of this approach can be extended to include "output grabbing" in a more general sense. Instead of recording bitmaps, it is also possible to store transmission protocol information, as is done in the University of Trier's VNC-based TeleTeachingTool (TTT 2002) and in the University of Mannheim's RTP/I-based Interactive Media on Demand system (Hilt et al. 2001).

A third approach is to use a tool specifically designed for the presentation and recording of course contents, providing features that are particularly useful for this task. Our own recording system, Authoring on the Fly (Müller & Ottmann 2000), and its commercial descendant, imc Lecturnity Suite (imc 2002), are examples of such an approach, as are PresenterONE (Accordent 2002) and Georgia Tech's eClass project (Brotherton 2001).

Blendings of different approaches can also be found such as the system proposed in (Dal Lago et al. 2002), which synchronizes the instructor's video with a second video stream for class materials, which can be imported from any video source like overhead camera, PC, VCR, or others.

3. Criteria for the Evaluation and Comparison of Presentation Recording Systems

One of the common features of all presentation recording systems is the capture of the instructor's verbal narration. It is quite obvious that without this, an essential and substantial part of the information will be missing. In addition, all presentation recording systems include the presented slides in the recorded documents. The major goals are to capture as many of the relevant media streams as possible, to preserve

the live character of a presentation, and to provide a comfortable navigation within (and in between) recorded documents. This also means that a tightly synchronous replay of all media streams must be possible regardless of the machine used to play back the recording. Simply capturing starting times of events (such as launching an application) can result in streams drifting apart, depending on the performance of the replay machine.
All of the recording should be done with the highest possible degree of automation and the lowest possible degree of obtrusiveness. Note that most presentation and recording systems require the instructor to directly interact with the computer during the lecture. One of the challenges to be solved in general is how the user interface for the lecturer can be designed such that it deviates as little as possible from the traditional blackboard-and-chalk paradigm.
The following criteria illustrate the differences between particular software approaches to presentation recording, leaving out all the hardware aspects that might be involved. While we do not claim our list to be complete, it contains the features which we consider most important, judging from our experience of using presentation recording in a university environment (see Datta & Ottmann 2001). We will also mention systems which provide a good sample of each particular criterion listed.

Representation of Contents

Simply videotaping lectures does not only lead to unacceptable quality of the filmed blackboard or slides. Even if this shortcoming might be improved with better technology, standard video formats have one additional major drawback: the information is not represented symbolically but as a series of bitmaps over time. Thus, it will involve tremendous effort to retrieve information from such a recording and to allow, for instance, full-text search within a lecture document.
It is therefore desirable to preserve all symbolic information of the original contents wherever possible. Apart from searchability, this representation yields some more advantages. First, text and vector graphics can be scaled without loss in quality to fit different screen resolutions on replay machines, while bitmap images will always suffer when enlarged or scaled down from their original size. Second, symbolic representation facilitates later manipulation of contents, for example, to remove errors or change attributes of objects. And third, it is also likely to reduce the amount of data compared to video formats.
Very few of the recording systems known to us preserve the symbolic representation. Of these, Lecturnity is the only one that also provides an integrated full-text search to find slides containing search strings.

Dynamic Capture and Replay of Annotations

In the educational domain of the natural sciences but also many others, instructors do not confine themselves to the presentation of pre-produced material. Rather, they will annotate the slides presented or even start from a completely empty page (or blackboard) and gradually develop complicated lines of thought using handwriting and graphical objects. In computer-assisted presentations, some dynamics may be introduced through animations provided by commercial presentation systems (such as MS-PowerPoint). The possibility of handwritten annotations, however, allows for much more flexibility; examples include answering student questions, addressing new aspects, detailing a mathematical proof (see Fig.1), and many more. It is one important requirement that it should be possible to dynamically record handwritten annotations such that they can be replayed synchronously with the verbal narration.
Of course handwritten annotation requires suitable hardware. Currently we are still far away from input devices providing the look and feel of traditional blackboards and chalk. Fortunately, new input devices such as electronic whiteboards or pen-sensitive displays have somewhat improved the situation.
Although PowerPoint itself allows free-hand annotation on the slides, the recording plug-ins we know of, surprisingly, do not capture those annotations at all. Desktop grabbing tools naturally record all the dynamics on the screen or, like Camtasia, even offer their own annotation feature. One significant disadvantage of such a solution, however, is that the notes have to be erased manually since the recording tool does not "know" when a new slide or application is being shown. In systems like AOF, eClass or Lecturnity, where annotations are associated with the slide on which they were made, all notes will automatically disappear when the slide is changed and be visible again when returning to that slide later in the presentation.

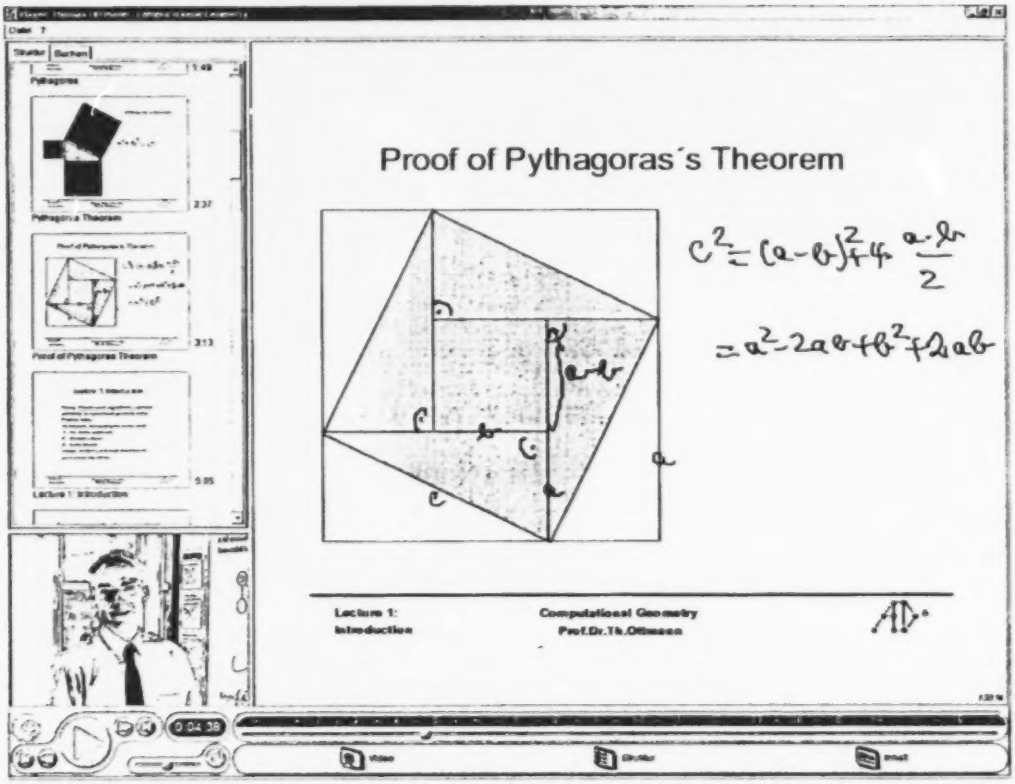

Figure 1: Replay of a lecture recorded with Lecturnity, featuring a thumbnail overview, a video or still picture of the instructor, the content frame with slides and annotations, and a navigation unit.

Structured Overview of Recordings

Comfortable navigation within the recorded documents must be one major goal. An overview or table of contents showing the structure of the captured session is an important method to facilitate navigation (Brusilovsky 2000). One way of implementing this can be thumbnails of the individual slides with links to the respective parts of the recording. Of course, such an overview should be generated automatically if possible. However, automatic structuring can only be achieved if the recording mechanism has some information about the presented contents, such as the timing of slide changes. A conventional screen recording tool does not have this information. The TeleTeachingTool tries to overcome this problem by identifying major changes in the captured images (which are likely to reflect slide changes), thus allowing the user to jump to the next slide. The video-based system in (Dal Lago et al. 2002) extracts slide titles to automatically index a video stream, but depends on the use of PowerPoint slides.
An automatically created, fully linked thumbnail overview is provided by AOF and Lecturnity (Fig. 1), which even supports different image sizes for the thumbnails.

Visible Scrolling During Replay

Another feature enhancing navigational comfort is fast visible scrolling, which allows students to browse through a recorded presentation by dragging a slider along a scrollbar. Of course, for this scenario to be user-friendly, the frame updates must display instantly during scrolling without a noticeable delay. In order to achieve this kind of navigation (which is similar to skimming through a book), the document format

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must support real-time random access. Note that if continuous media are delivered via a streaming server they cannot at the same time provide fast visible scrolling. This is because only a small part of the document is buffered locally at any given time. In order to make random access work in real time, the document as a whole must be stored locally.
Examples for systems supporting visible scrolling include AOF, Lecturnity, and some video formats if replayed locally (i.e., not streamed) using a suitable player.

File Format and Size of Recorded Documents

As mentioned above, if recordings are delivered to the end user via a streaming server, the feature of visible scrolling cannot be supported at the same time. On the other hand, if the files are to be downloaded by the students, file size should not be neglected, even though the increasing availability of broadband connections is likely to make this a minor problem in the future.
It is, of course, desirable that the recordings have a platform-independent format, or even better, a standard "web-based" format (such as HTML, Flash, MPEG, RealMedia, etc.). That way, users will not have to install additional software on their computers, as most operating systems or web browsers will be ready to replay the documents. On the other hand, many of those formats do not support real-time random access which is necessary for visible scrolling, and therefore lack an important navigational feature.
Producing a video from a computer presentation by screen grabbing, i.e. by taking a series of, say 10 screen shots per second and compressing the resulting movie using the standard video codecs of the MPEG family does in most cases neither lead to acceptable quality nor to a reasonable size of the compressed file. Special lossless codecs are required to compress this kind of video (Deshpande & Hwang 2001).
Camtasia offers a great variety of formats for the export of grabbed videos and, with TSCC, provides a very powerful lossless codec particularly suited for videos resulting from recorded screen contents.

Formats of Materials Which Can Be Captured

The ultimate goal of presentation recording is to record all relevant media streams occurring in the live session. This includes the support of any given file format or application used by the instructor. Tools recording desktop contents, like Camtasia, can capture virtually any material displayed on the screen.
However, there will always be a trade-off between the number of usable raw formats and other features. For example, in order to automatically create a fully linked table of contents, the recording tool has to "know" the materials in the sense that slide changes, annotations, or calls of external applications all have to be done from within (or at least be recognized by) the recording system. A tool which simply grabs screen or window contents, although it can capture virtually any material displayed on the screen, will not be able to automatically generate a structured overview of a recording.

Capture and Integration of Live Video

A video picture of the instructor provides a visual impression as well as a feeling of the instructor's "presence." On the other hand, in relation to the amount of data video usually conveys very little information, except if showing objects or experiments relevant to the subject discussed in the course. The importance of integrating live video should therefore not be overestimated. A static image of the instructor will often be sufficient and reduce the amount of data drastically.
If live video is to be included, the process should be automated and involve as little manual work as possible. In this respect, the PowerPoint add-ons RealPresenter or Microsoft Producer are among the most comfortable tools.

Post-Editing Facilities

Whether or not recorded presentations can or should be post-edited is not only a matter of available resources but also of personal taste and perfectionism. In order to preserve the live character of a

presentation, it might even be the best thing to avoid later changes completely. Nevertheless, some facility for post-editing the recordings is definitely a useful tool.
There are quite a number of editing tools available which make it easy to cut and join parts of different recordings if they are in a video format. However, as mentioned above, the contents of slides can best be manipulated if they are represented symbolically. For example, erroneous text on a slide may hardly be corrected later if the recording is in a video format, while there will be no problem if it is still represented as a text object. However, one might have to edit large files "by hand," since none of the systems featuring symbolic representation offers a user-friendly editor. Among the other tools, Camtasia probably offers the most comfortable solution for cutting and joining recordings.

Turning Recordings into a CD-ROM or Web-Based Course

In order to really make use of the recordings as parts of integrated e-learning modules, there should be an easy way to combine the documents with exercises and other materials and to organize the courses in a web-based learning management system or on distributable storage media like CD-ROM or DVD. Automated processes, interfaces, or metadata are possible methods for facilitating such an integration. Furthermore, the random access capability can provide a convenient way to link presentation recordings to other web-based material.
AOF with its open format can easily be post-processed by batch scripts. Lecturnity and PresenterONE prompt the user to enter metadata such as author, keywords etc. for each recording and also include tools for publishing collections of captured talks on the web or CD-ROM.

	Symbolic representation	Dynamic capture of annotations	Structured overview	Visible scrolling	Standard format for replay	Supported input formats	Live video	Post-editing	Creation of web-based courses
AOF	✓	✓	✓	✓	optional conversion to Real[1) 9)]	ppt[2)], gif, png, jpg, ps[3)]	✓[4)]	✓[5)]	Scripts, metadata
Camtasia	—	✓	—	✓[6)]	avi, wmv, asf, mov, Real etc.	any (screen recording)	✓	✓	—
eClass	—[14)]	✓[15)]	✓	—	HTML, RealMedia	gif, jpg, HTML	✓	—	✓
IMoD	✓	✓[12)]	✓	—	—[7)]	multi[8)]	✓	—	Tools for creating CBTs
Lecturnity	✓	✓	✓	✓	optional conversion to Real[9)]	ppt[2)], gif, jpg, png	✓[4)]	—	Metadata, publishing assistant
MS Producer	✓	—	✓	—	extended HTML (IE5 only)	ppt[10)]	✓	✓	✓
PresenterONE	—[14)]	—	✓	—	RealMedia	ppt[11)], HTML	✓	✓	Metadata, publishing assistant
TeleTeaching Tool	—	✓[12)]	—	—	—[13)]	any (screen recording)	✓	—	—

1) Semi-automatic conversion; dynamic replay of annotations is lost.
2) A PowerPoint 2000 add-on converts slides, retaining basic PowerPoint features.
3) PostScript import possible in the Linux/UNIX versions.
4) No automated process, some manual work is necessary.
5) A basic AOF editor is available for Linux.
6) Depending on the format and player software.
7) Slides are in HTML. Audio and video are replayed in a Java applet. To replay other streams, the applications used for recording must be installed on the replaying machine.
8) The applications used must be RTP/I based.
9) Visible scrolling is not possible in RealMedia format.
10) Including animations and embedded objects (video etc.).
11) PowerPoint Slides are converted to GIF or JPEG images, resulting in loss of most PowerPoint features.
12) No built-in annotation facility, but those provided by suitable applications (e.g., Adobe Acrobat, mlb) can be used.
13) Audio is in MP3 format.
14) Slides are imported as GIF or JPEG images, HTML pages remain.
15) No dynamic replay of annotations.

Table 1: Overview of presentation recording systems and supported features

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4. Overview of Existing Systems

Although a variety of presentation recording systems is available today, none of them can be considered ideal in the sense that all of the features listed above are supported to a satisfying degree. (Tab. 1) provides an overview of a number of existing systems and the criteria they meet.
The major conflict between different criteria is easily identified: Screen grabbing systems are very flexible in that they can record almost any material, while all other systems are restricted in this respect. On the other hand, none of the screen recorders are able to automatically create structured overviews of the courses, a feature which is extremely important for comfortable navigation in web-based lectures (Brusilovsky 2000). Moreover, information retrieval in large repositories of recorded presentations becomes difficult or even impossible if the data of the recordings are not stored symbolically.
One way out of this dilemma of conflicting criteria seems to be a presentation system offering an integrated screen grabbing utility that can capture external applications on demand and automatically link the screen recordings with the rest of the presentation. At the moment of writing, we do not know of any such system.

5. Technical Challenges

Apart from the problem of finding a good compromise for the conflicting criteria indicated above, there is a number of technical challenges which need to be addressed, both hardware and software related.
One example of a desirable feature would be a convincing implementation of an optimal user interface for lectures, including, for example, gesture recognition in order to erase, collapse, or expand handwritten annotations. It is obvious that the currently dominating desktop paradigm is not adequate for a lecturer interacting with a wall-sized interactive whiteboard. A number of convenient tools like an "e-sponge" are required in such a scenario.
Lecturers using a pen-based input device during a computer presentation tend to make extensive use of it. Unfortunately none of the currently available presentation and recording systems maintains the individual and personal flavor of the lecturer's handwriting. In fact, the writing often looks scrawly and childlike. The fact that none of the recording tools is able to use all the information provided by modern input devices (e.g., the weight put on the electronic pen) is only one reason for this.
The more serious problem is that the trace of the pen is often just stored as a sequence of input vertices. Processing the handwritings by anti-aliasing or online smoothing may improve the appearance of the pen trace. However, no satisfying compromise has so far been achieved between the conflicting goals: symbolic, vector-based representation of recorded free-hand writing on the one hand in order to keep the amount of data low, and support of pixel-based operations (such as erasing, insertion, deletion), personalization and adaption to different pen styles (chalk, ink, etc.) on the other hand.

6. Conclusion

Presentation recording can be used as a cost and time saving method to create web-based course materials from live lectures. Our experience gained in two government-funded projects (ULI 2002, VIROR 2002) involving several German universities has shown that lecture recording is well-received both by instructors and by learners. Within the past years, more than 250 hours of computer science classes have been recorded with different tools at our university and have served as a basis for web or CD-ROM based courses.
In this paper we have described several technical approaches and presented a list of criteria by which different recording systems can be evaluated for their use in a traditional university environment. One major problem we have identified comparing the tools available today is the conflict between a symbolic representation of contents in recorded documents on the one hand and flexibility regarding the range of recordable formats on the other hand.
There are features which most currently available presentation recording systems leave to be desired, such as a satisfying support of alternative human-computer interaction paradigms, which would allow instructors to completely maintain their familiar style of teaching. Another area of future investigation is a data structure to represent dynamic handwritten annotations on slides in a both comfortable and efficient way, supporting vector-based as well as pixel-based operations.

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